

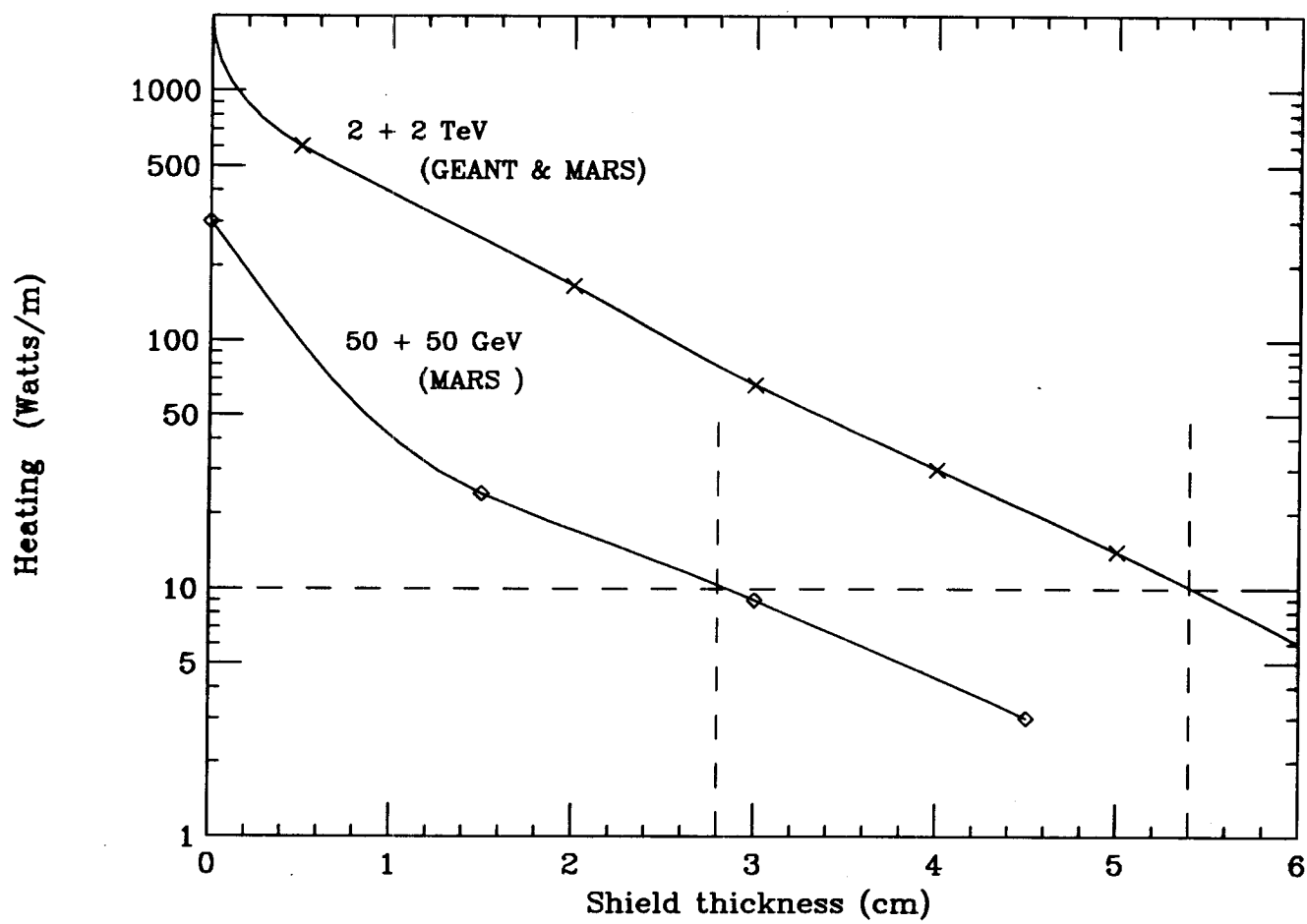
## **Magnet Challenges - Technology & Affordability**

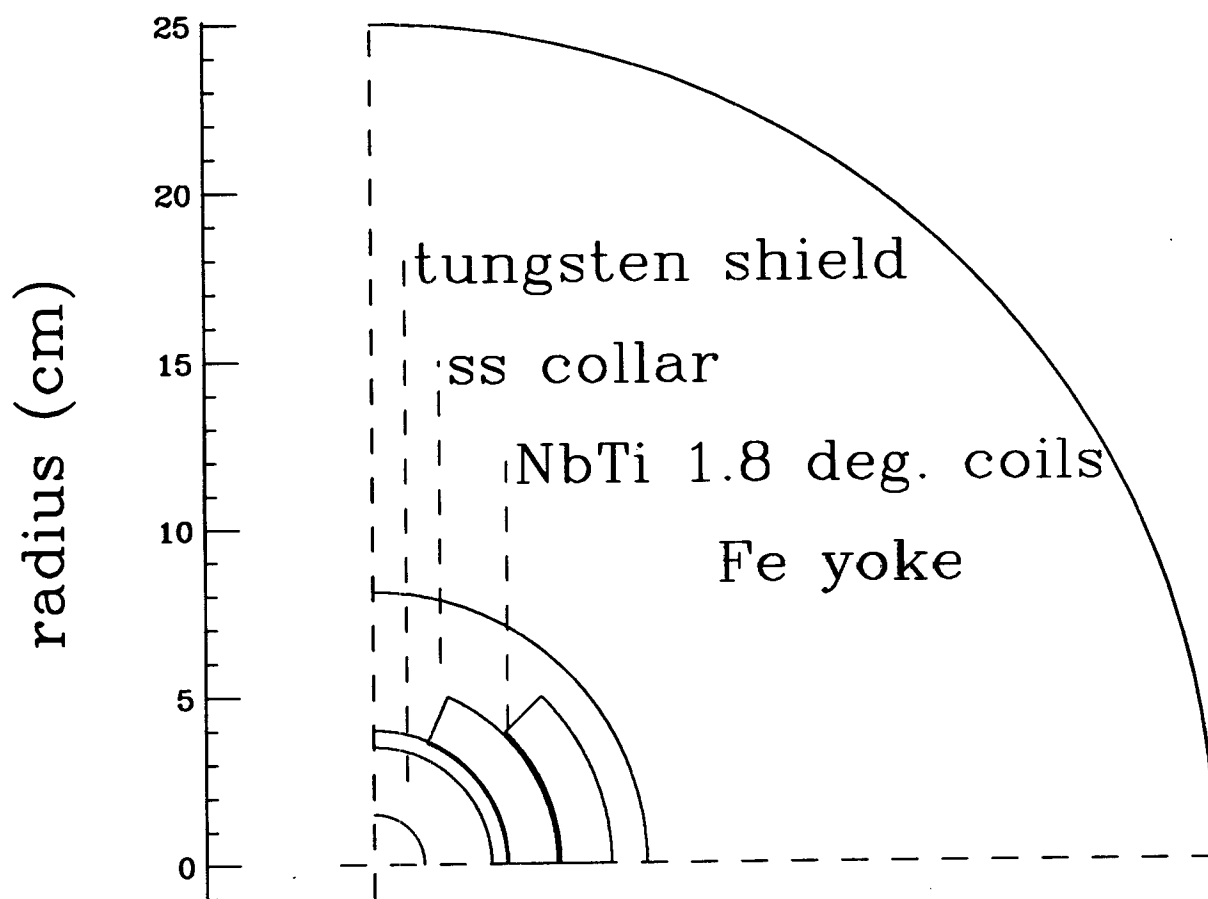
- Technical Requirements
- Conceptual Approaches
- Magnet R&D status in the U.S.
- Heat Load Issues
- Comments on costs

Center of mass energy, $E_{COM}$	$10^4$		$10^5$		$10^6$	
	0.1 to 3 TeV	10 TeV	100 TeV	100 TeV	100 TeV	ultra-cold beam etc.
Additional Description	MC Collab. status report	evolutionary extrapolation	evolutionary extrapolation	evolutionary extrapolation	ultra-cold beam etc.	

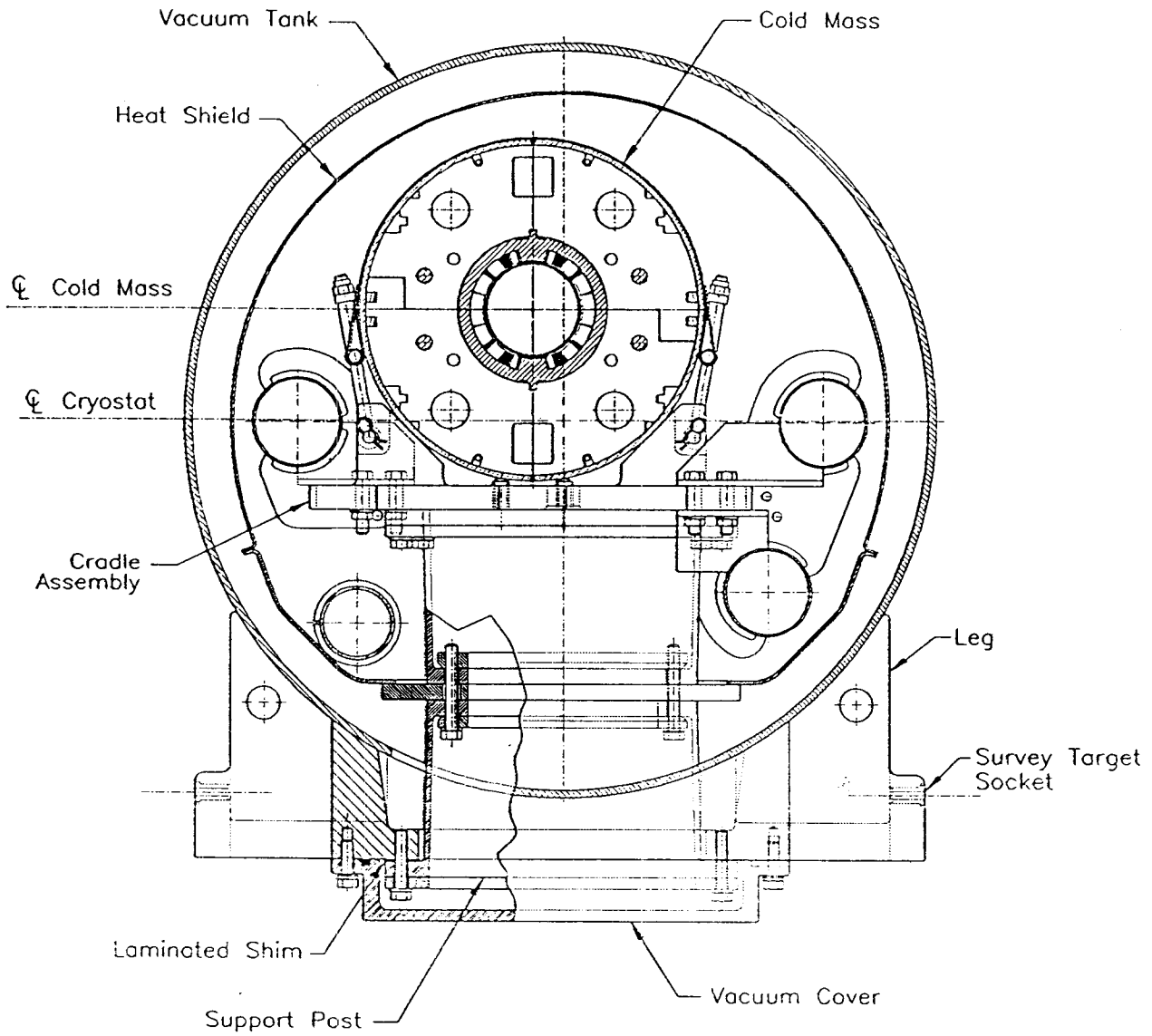
collider physics parameters:						
luminosity, $L [cm^{-2} s^{-1}]$		$8 \times 10^{30} \sim 5 \times 10^{34}$	$1.0 \times 10^{36}$	$1.0 \times 10^{36}$	$1.0 \times 10^{38}$	
integrated $L [fb^{-1}/yr]$		$0.08 \sim 540$	10 000	10 000	$1.0 \times 10^6$	
# of $\mu\mu \rightarrow ee$ [events/year]		$650 \sim 10\,000$	8700	$\approx 87$	8700	
# of 100 GeV SM Higgs/det/year		$4000 \sim 6 \times 10^5$	$1.4 \times 10^7$	$2.1 \times 10^7$	$2.1 \times 10^9$	
frac. CoM E spread, $\sigma_E/E [10^{-3}]$		$0.02 \sim 1.1$	0.42	0.08	0.07	

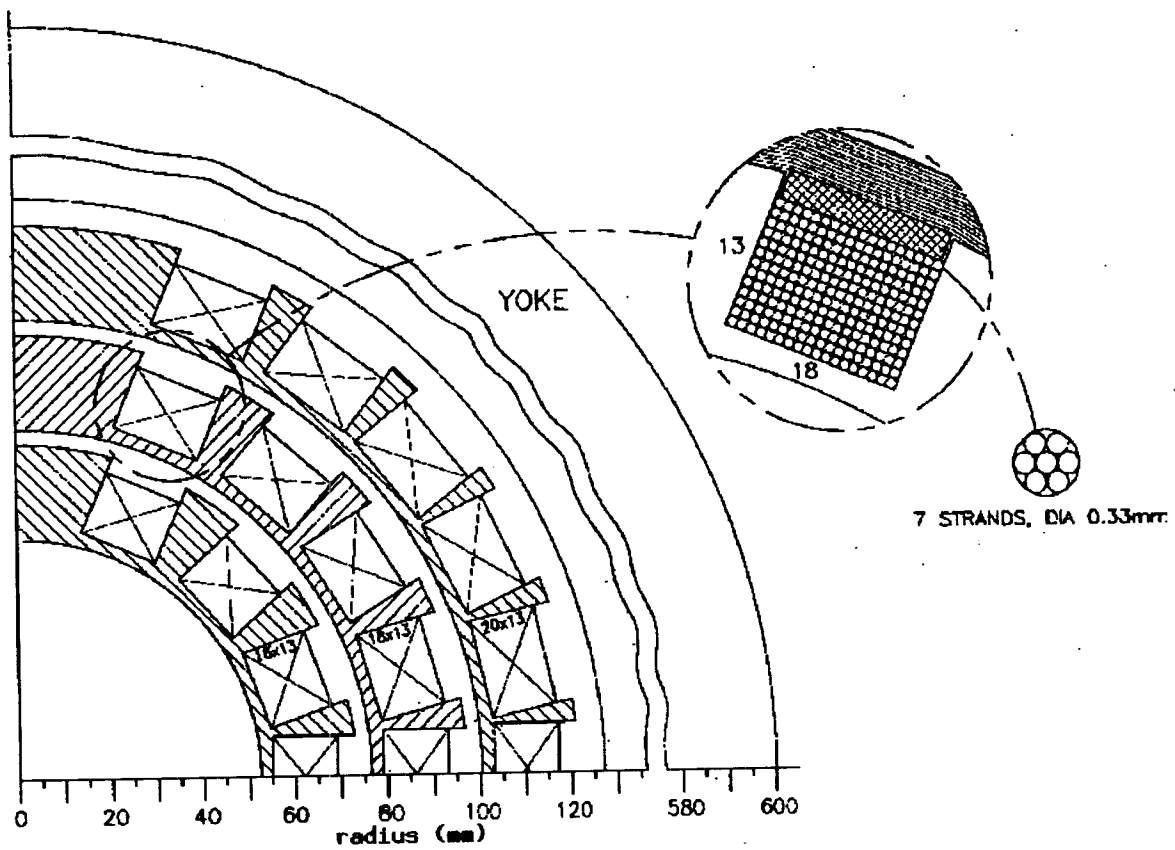
collider ring parameters:				
circumference, $C [km]$		$0.35 \sim 6.0$	15	100
ave. bending B field $[T]$		$3.0 \sim 5.2$	7.0	10.5





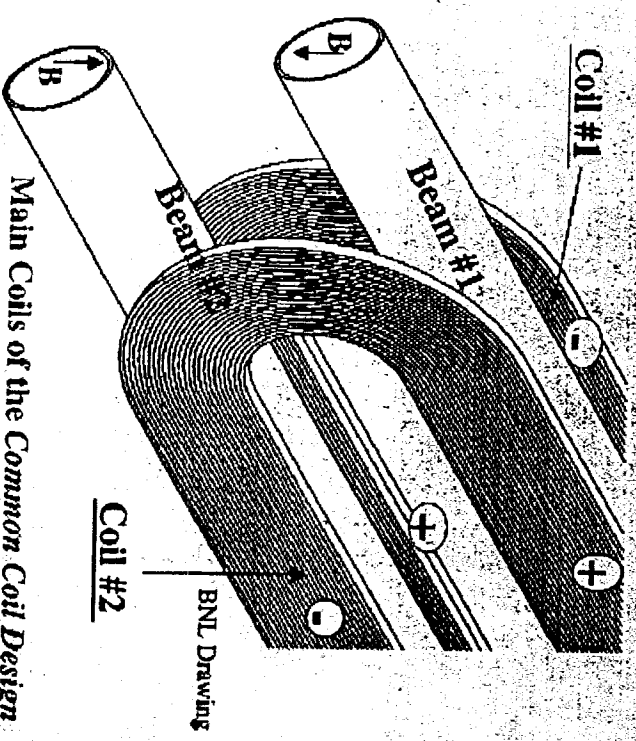
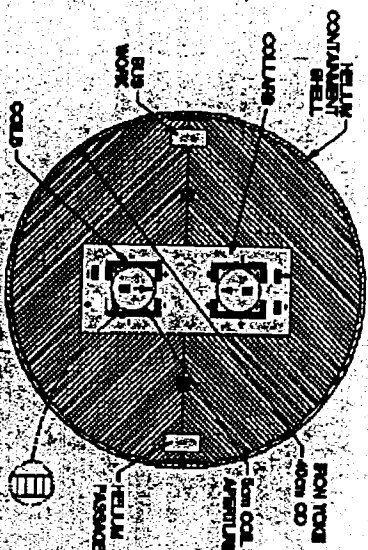
Center, Fixed Cradle







# Common Coil Design (The Original Concept)

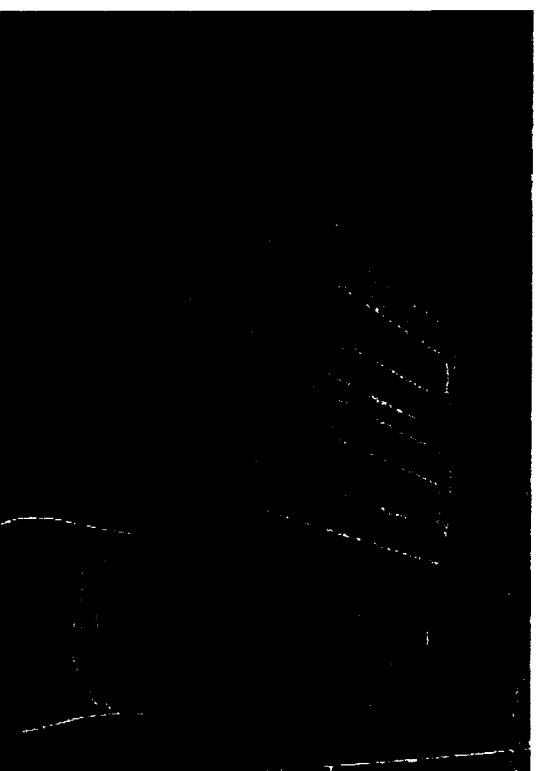


Main Coils of the Common Coil Design

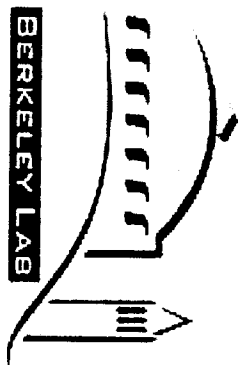
- Simple 2-d geometry with large bend radius (no complex 3-d ends)
- Conductor friendly (suitable for brittle materials - most are, including HTS tapes and cables)
- Compact (compared to single aperture D20 magnet, half the yoke size for two apertures)
- Block design (for large Lorentz forces at high fields)
- Efficient and methodical R&D due to simple & modular design
- Minimum requirements on big expensive tooling and labor
- Lower cost magnets expected

# BNL Common Coils

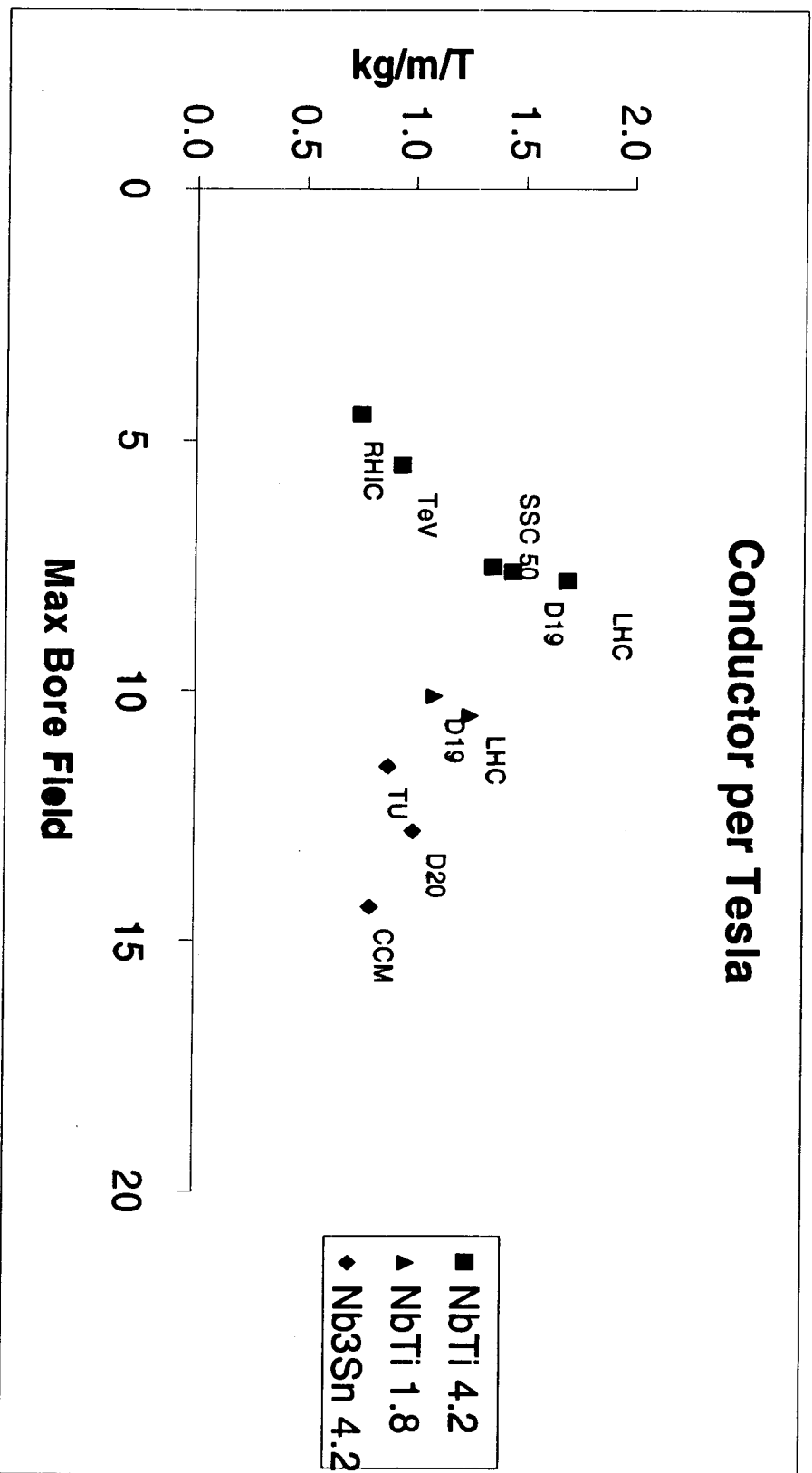
- HTS coil (30 cm)
  - tape
- $\text{Nb}_3\text{Sn}$  coils (1 m)
  - tape
- NbTi coil (1 m)
  - background field
  - SSC cable







## Conductor per Tesla



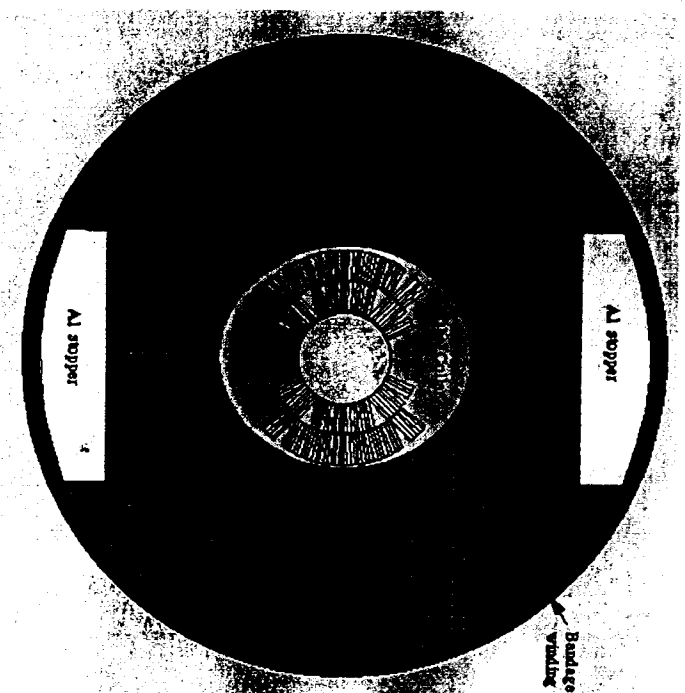
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# FNAL High Field, Cos $\theta$

- Use lessons learned in previous cos  $\theta$  magnets (mostly NbTi)
- Brittle materials:
  - wind & react vs react & wind
  - coil impregnation

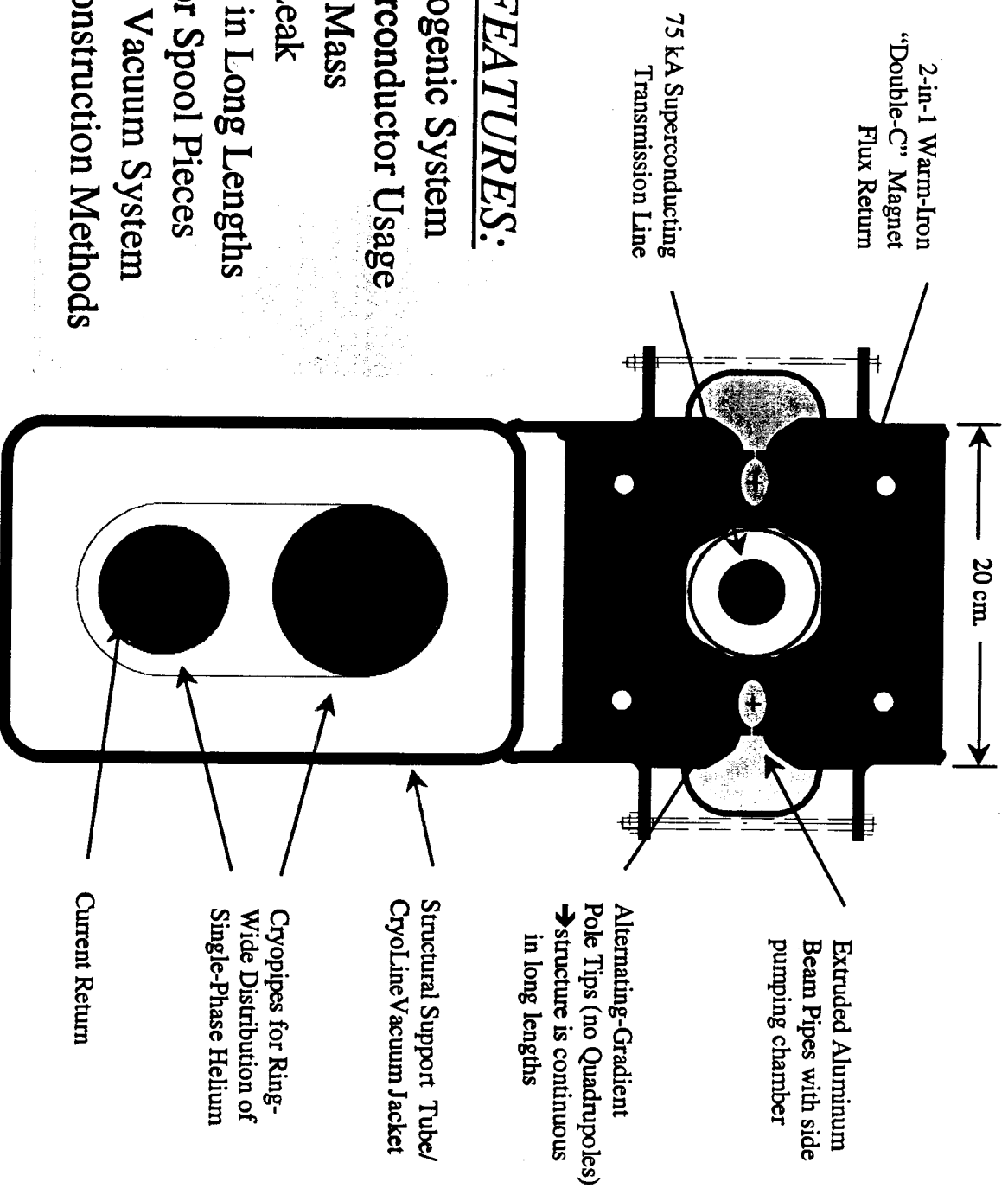


# Heat Loads

Com Energy	Shield Thickness	Magnet Aperture (diameter)	Magnet Heating (at 4K)	Cryogenic Power (wall plug)	
0.1 Tev	28 mm	86 mm	3 kW	2 MW	O.K.
4 Tev	54 mm	140 mm	50 kW	35 MW	O.K.
10 Tev	~60 mm	150 mm	135 kW	100 MW	?
100 Tev	~80 mm	190 mm	900 kW	600 MW	X

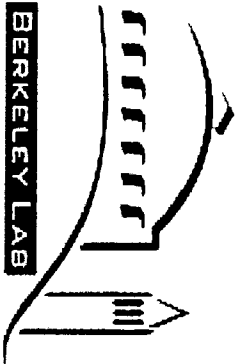
- Heat load also results in high  $\Delta t$
- HTS might help somewhat
- Low Field - Transmission line magnet could solve heat load but results in factor 5 loss in L (2T v's 10T)

# Transmission Line Magnet

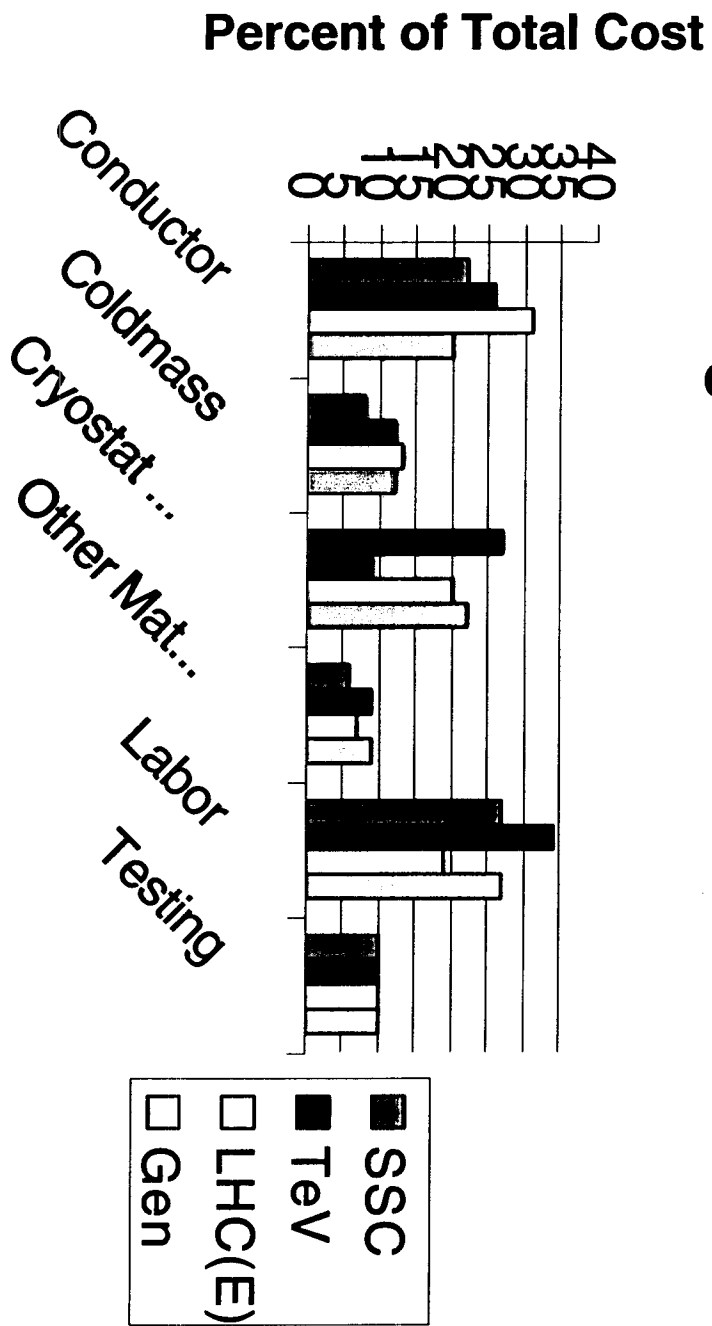


## KEY FEATURES:

- Simple Cryogenic System
- Small Superconductor Usage
- Small Cold Mass
- Low Heat Leak
- Continuous in Long Lengths
- No Quads or Spool Pieces
- Warm Bore Vacuum System
- Standard Construction Methods



# Magnet Cost Distribution



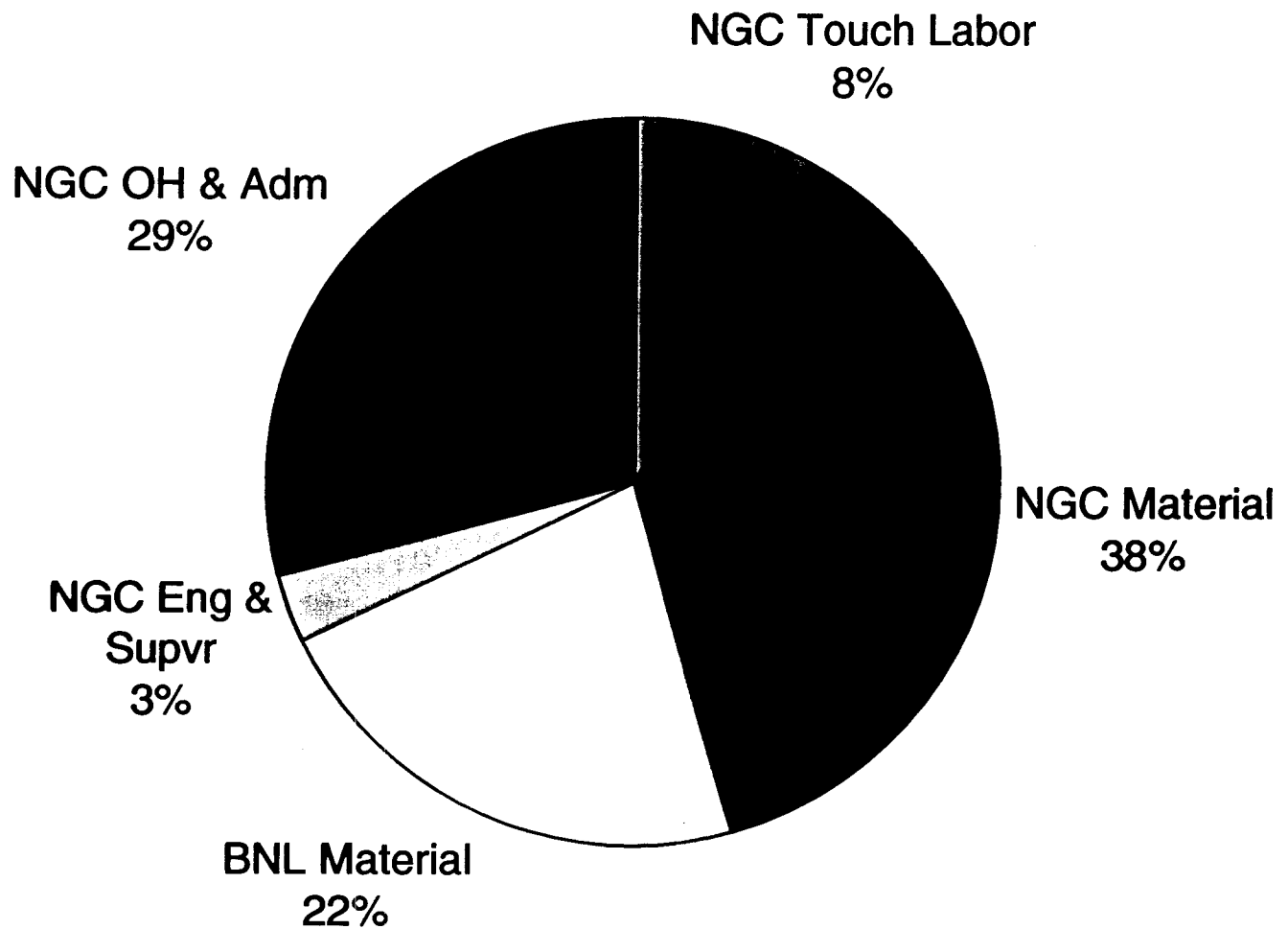
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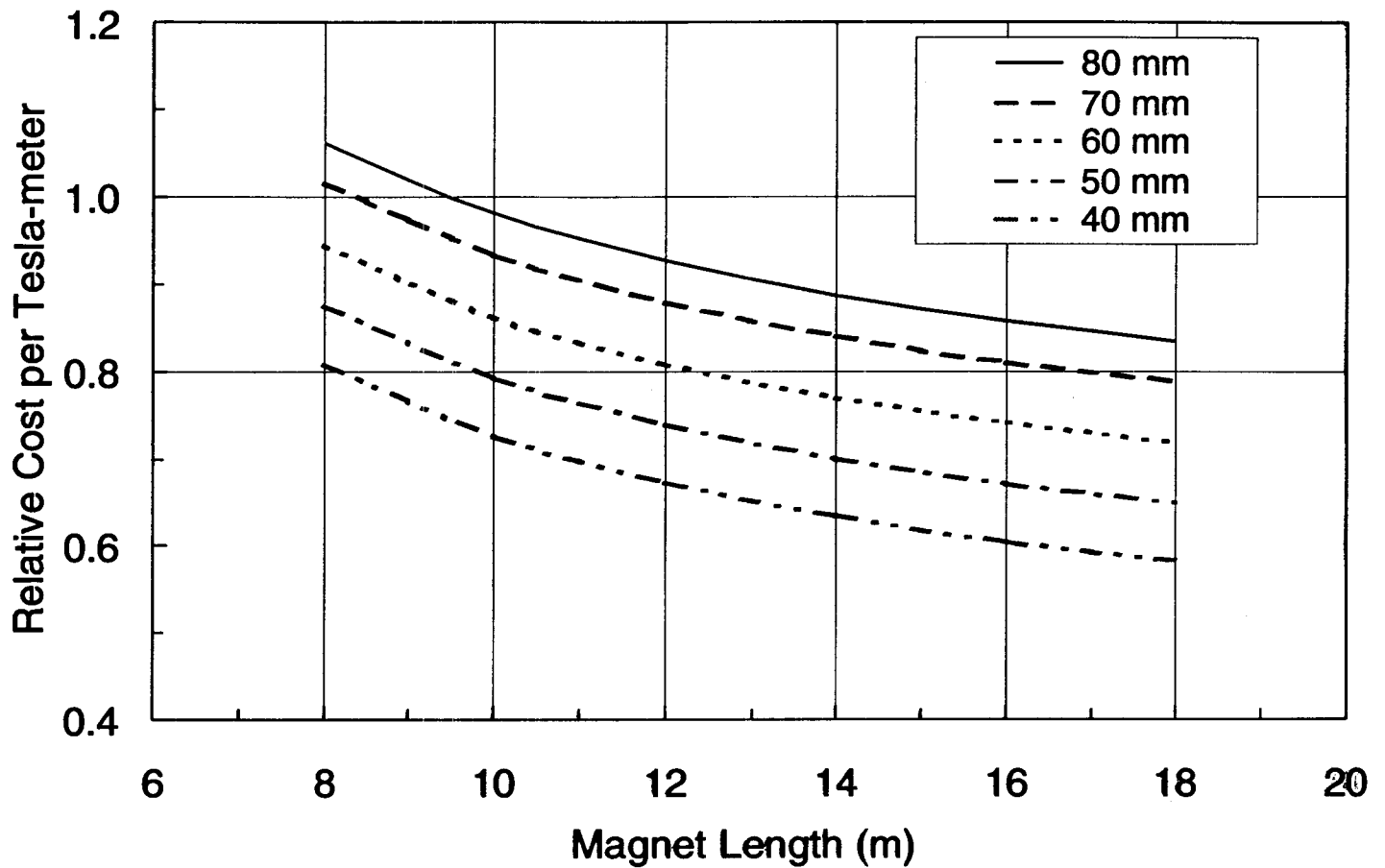
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## **Cost Components of Production Dipole Magnets**

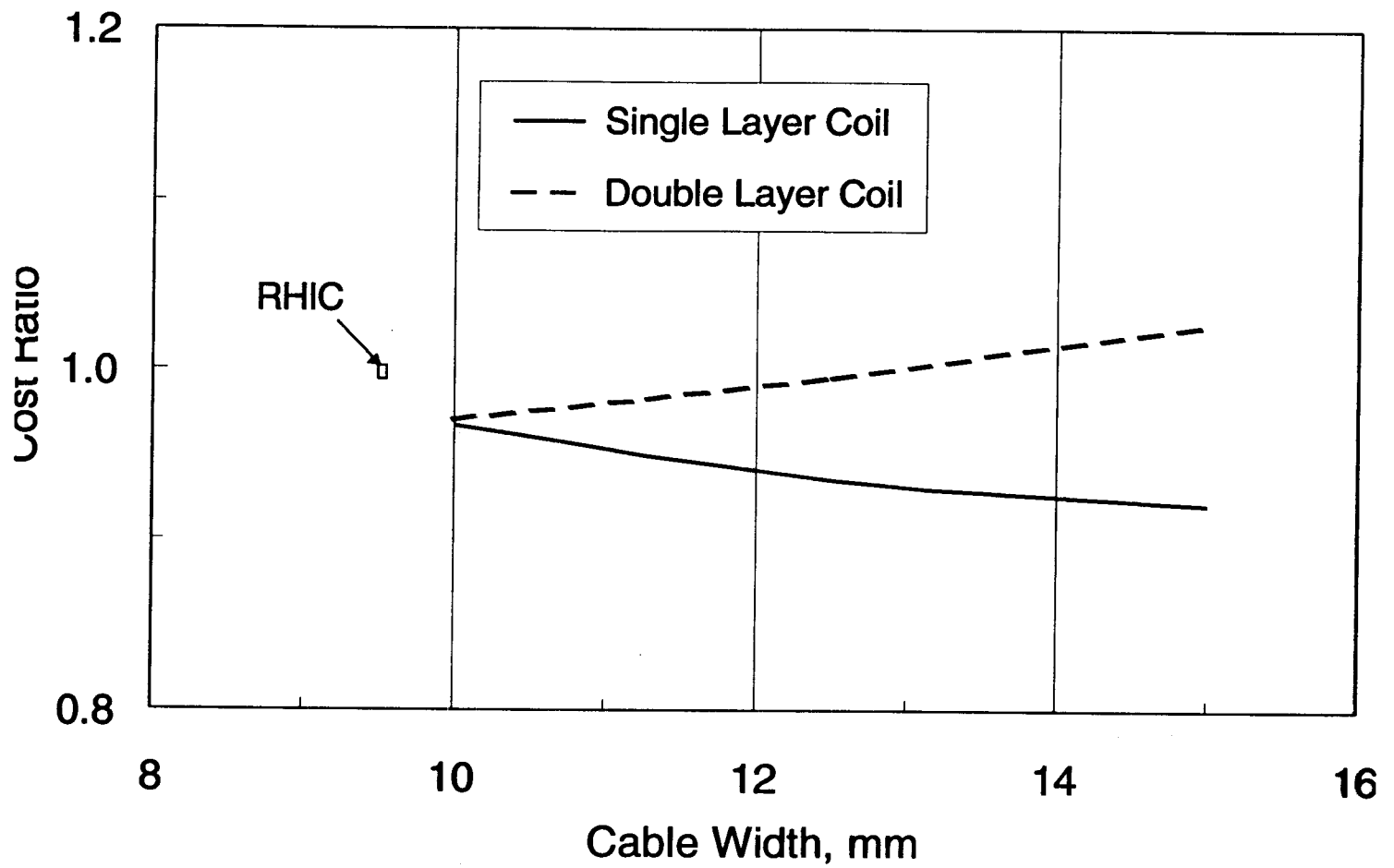
**Cost per magnet = \$109,366**



## Cost vs. Length Relative to RHIC Production Dipole Cost for Several Coil Apertures

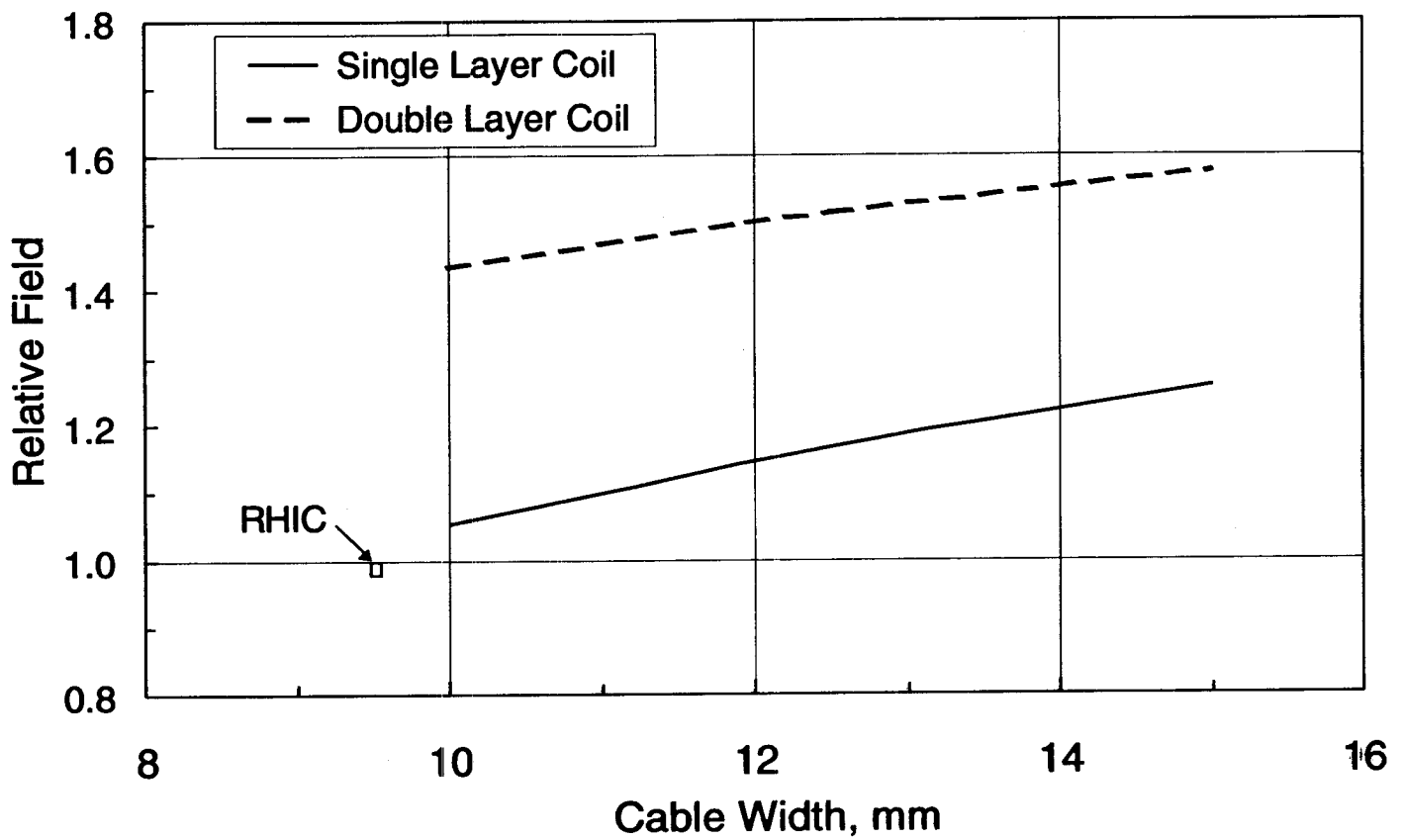


## Ratio of Cost per Tesla-Meter for Dipoles with Wider Cable and Second Coil, Relative to RHIC Dipoles

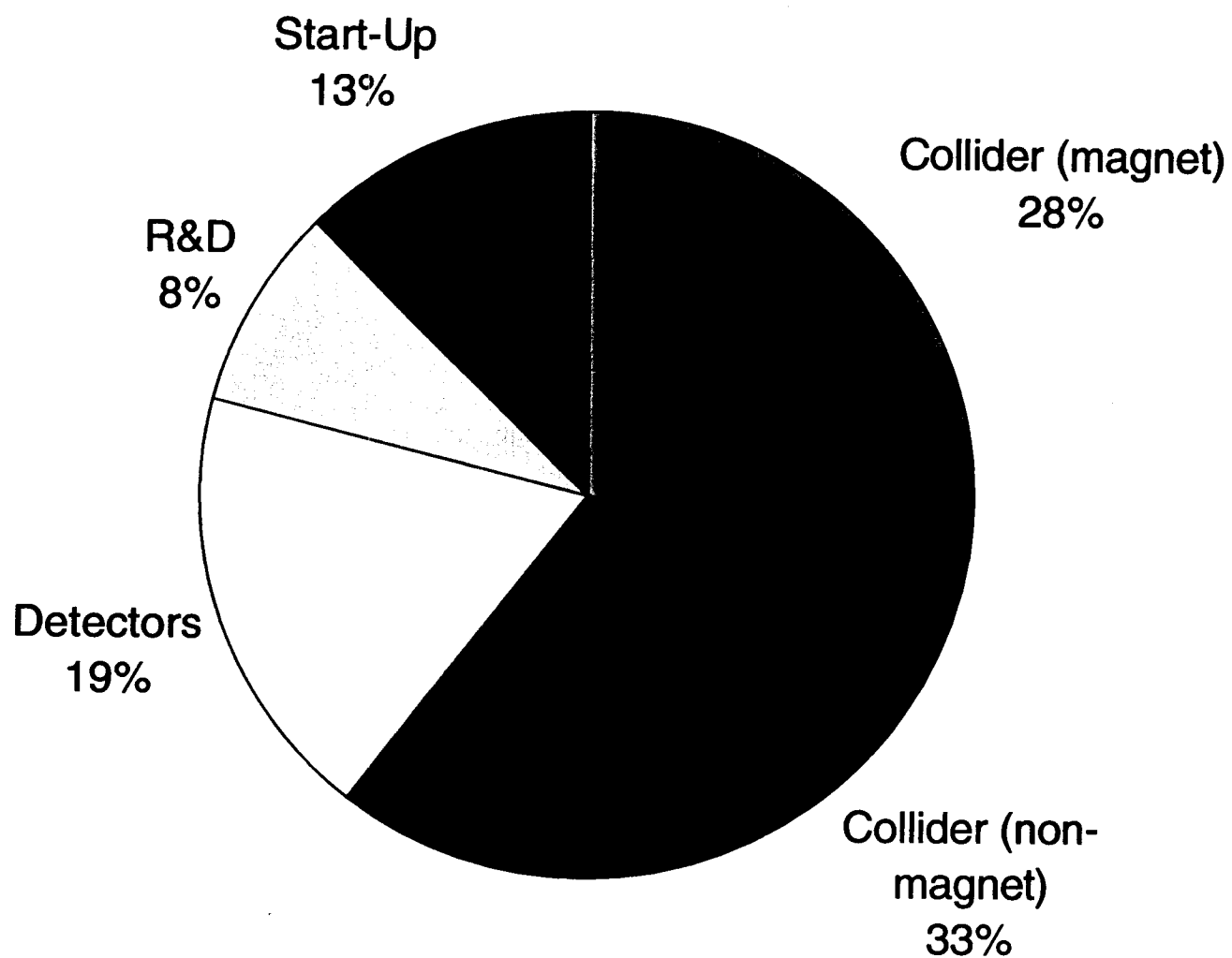




## Field Attainable, Relative to RHIC Dipoles, With Wider Cable and Second Coil



## RHIC Project Cost Components



# Affordability

- RHIC Dipoles 8cm, 10m, 4T, FY95 cost \$110K each
- HEMC Dipole
  - 8cm -> 15cm      50%
  - 4T -> 7T      50%
  - 10m -> 15m      40%
  - FY95 -> FY00      15%
  - Estimate HEMC Dipole \$400K or \$26K/m based on RHIC
- 10 Tev needs 15km circumference -> magnet costs ~\$400M. Ring costs = dipoles  $\times$  3(or4) = \$1.2(6)B (probably a lower bound since HEMC dipoles are more complex than RHIC)

# Sticker Shock

- LHC costs 2.4B sf. ~ \$1.5B (European estimate)

Or

- LHC costs      \$1.5B materials + \$3.0B labour ( 10 years of CERN @ \$300M per) + \$1.5B contingency + \$1.5B indirect = \$7.5B (U.S. estimate)

- Example SNS - \$1.3B
  - 1 GeV Linac
  - 1 GeV storage ring
  - 2-4 MW target

## **Conclusions**

- A 10 Tev machine based on Nb-Ti magnets (7T dipole) is challenging but possible
- A 100 Tev machine does not look feasible based on 10T cosine theta dipoles
- A different magnet design (no mid plane cryogenics) would help
- Newer technologies (Nb<sub>3</sub>Sn, HTS) would be beneficial assuming that costs are reasonable and they work
- Demanding technical environment + no obvious significant cost reductions appears to preclude a 'cheap' solution